Measurements of the Speed and Mean Life of Cosmic-Ray Muons as a Test of Special Relativity

Fiz A. Cyst

MIT - Department of Physics
Is there a relationship between velocity and time?

Special Relativity
- In 1902 Einstein published his theory...
- Objects moving near the speed of light...
- Time dilation ...

Muons
- Former MIT Professor Bruno Rossi observed cosmic ray muons...

Einstein - Circa 1912
Rossi - Circa 1987
Make Slide Titles Informative!
...and keep your audience focused.

- Summary of Key Physical Relationships - NO LONG DERIVATIONS!
- Identify assumptions, e.g. data are Poisson distributed, our calculations disregard 2nd order effects, etc... characterized by, $\sigma_i$
- Maximizing the probability of the dataset $\Rightarrow$ Minimizing $\chi^2$

$$\chi^2_{\nu} = \sum \left[ \frac{y_i - f(x_i)}{\sigma_i} \right]^2$$

- If you show present equations, you MUST identify every variable.
- Also try to tell what the equation MEANS!!!
  - $\chi^2_{\nu} >> 1 \rightarrow$ Bad fit
  - $\chi^2_{\nu} << 1 \rightarrow$ Probably overestimated errorbars on data
A spin evolves in a magnetic field according to the Hamiltonian \( H = \vec{\mu} \cdot \vec{B} + H_{RF} \).

Free precession is

\[
R_z = \exp[i\omega_z t \sigma_z/2]
\]

Note all text on plots should be at least 16 point!
Don’t bombard your audience with too many details but DO identify critical elements.
Always present some of your raw data...

- Identify things like integration time, any instrumental gain and/or filtering...
And some reduced data...

Fit Result Graphics Should Contain All Pertinent Information

$y(x) = a_1 e^{-a_2 x} + a_3 e^{-(x-a_4)^2/a_5^2} + a_6 e^{-(x-a_7)^2/a_8^2} + a_4$

$\chi^2_{v-1} = 0.82$

- Explicitly state where your uncertainties come from!
- If residuals are significant, plot and discuss!
Muon Time of Flight Vs. Relativistic Prediction

Always compare to a physical model!

MCA Energy Calibration using $^{133}$Ba

Energy = $(1.109 \pm 0.025) \times \text{Channel} - (2.149 \pm 7.302)$

As you can see our data show a discrepancy at higher energies...
Results and Interpretation

- Give results as $x = (y_{\text{yy}} \pm \delta y_{\text{ys}} \pm \delta y_{\text{ran}})10^{zz}$ and compare to known values in terms of being so many standard deviations away...
- Description and Analysis of Errors, show how $\delta y$ is made up, discuss random and systematic contributions.
- If you’re more than $3 \sigma$ away from the known value, prepare to suggest possible systematics and persuasively argue their likely order of magnitude.
- What calibrations would you like to have performed...
Summary and Conclusions

- Does the data support your conclusions?
- If not, why not (speculate but be prepared to defend your reasoning!)
- Things you could have done better...

- The first main message of your talk in one or two lines.
- The second main message of your talk in one or two lines.
- Perhaps a third message, but not more than that.
Final Thoughts

- This template is just a guide. Slides may be added or removed based on length of talk, target audience or instructor advice.
- Bring a paper copy of your slides to your exam just in case you have AV difficulties.
- Arrive 10 minutes early and dress as you would for any other important public presentation.
- Practice, practice, practice!